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THE MISSION AND SYSTEM DESIGN OF THE LUNAR BOREHOLE NEUTRON DETECTION PAYLOAD

Abstract

Lunar neutron radiation originates from the spallation reactions between high-energy cosmic rays and the atomic nuclei of lunar regolith. Due to the absence of an atmosphere and a global magnetic field on the Moon, lunar neutrons represent a unique environmental element for lunar exploration activities. Compared to electrons and gamma, neutron radiation poses a more severe risk to human health, causing cellular apoptosis and chromosomal aberrations, with radiation weighting factors being 5-20 times higher than those of electrons and gamma. The results of the Chang'e-4 mission show that neutral particles contribute up to 23.5% of the total dose on the lunar surface. The intensity of epithermal neutron on the lunar surface is directly related to the hydrogen content within the lunar regolith. Detecting epithermal neutrons provides a main method for the exploration of lunar water resources and the study of the origins and evolution of water ice. Given the importance of lunar neutrons for human lunar exploration, we propose a lunar borehole neutron detection payload mission. We intend to use high-detection-efficiency helium-3 proportional counter tubes to measure the vertical distribution of epithermal and thermal neutron fluxes within lunar boreholes. The payload includes three helium-3 proportional counter tubes, one cadmium-coated tube, and one tin-coated tube connected in series, vertically placed in the borehole formed after lunar drilling, and adjusted in depth by a stepper motor. Another cadmium-coated helium-3 tube is placed on the lunar surface to measure the intensity of epithermal neutron flux, primarily to eliminate the systematic error caused by cosmic ray variations, ensuring high-precision measurements of the water content in lunar regolith. To date, only the Apollo 17 mission has measured the neutron density within 2 meters depth of lunar regolith. The lunar borehole neutron detection payload can be widely deployed in boreholes formed after lunar soil drilling, and is expected to obtain neutron fluxes over a greater depth range. The lunar borehole neutron payload can, for the first time, obtain the vertical distribution of water content within lunar soil in situ, while neutron radiation measurements at different depths can provide important reference data for radiation protection at the International Lunar Research Stations. This paper will provide a detailed introduction to the scientific and engineering objectives, design schemes, and other aspects of the lunar borehole neutron payload.